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POPULATION INVERSION NON-EQUILIBRIUM FLOW SIMULATION CALCULATIONS A STUDY
OF THE CAPABILITIES OF CONVECTION FLOW LASERS

by

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I. INTRODUCTION

In the 1940s, the thermodynamics of non-reversible processes had already formed a new field [1]. By the beginning of the 1960s, diffusion, thermal conductance, electrical conductivity, relaxation, as well as thermoelectrics, electromagnetics, and other similar non-reversible processes, in their various types of treatments, had already been pulled together to form a unified system - non-equilibrium state thermodynamics [2]. Due to the study and development of heat engines, gas electrical discharges, thermonuclear fusion, as well as celestial mechanics, geophysics, and other similar areas, fluid mechanics and non-equilibrium physics were united to form the study of non-equilibrium flow problems which has already expanded into a broad field. Fluid mechanics and non-equilibrium state thermal dynamics are brought together to form "hot gas dynamics". Electromagnetic dynamics is brought into this to form "magnetic fluid dynamics", and so on, and so on. In the last decade or so, the test production of high power lasers has quickly developed. The flow movements of working media have important effects on high power laser devices. (1) The convectionary heat diffusion in flow movements is much more effective than non-flow diffusion heat dissipation. (2) Flow movements make the working medium constantly replace itself. This makes it possible to maintain the stability of the working medium as well as to continuously replenish the energy source. (3) It is possible to make use of rapid expansion to directly form population inversion. Because of this, the high power lasers which currently exist - gas flow lasers, flow movement and electrical discharge lasers, quasimolecular lasers, chemical lasers, and other similar devices make use of ⟨...⟩ flow gases to act as working media.

The basic condition for the production of laser light is working medium population inversion. Moreover, the inverted state is most certainly a type of non-equilibrium state. In flow movement laser devices, one finds the types of non-equilibrium problems set out below: (1) as far as this type of population inversion non-equilibrium flow is concerned, considering radiation, electrical discharge, chemical reactions, various types of relaxation (vibratory, rotational, and collision) as well as media flow speed and the

importance of other similar factors, the need to present a research model which is appropriate, (2) for the various types of factors presented above, treatment and calculation methods, (3) this type of non-equilibrium flow and its mixing process fluid dynamics equations as well as their explanation, (4) the various types of factors discussed above as well as their changes and working media states as well as population inversion and their mutual effects and rules or patterns (5) the microscopic dynamic mechanisms for the processes concerned, and, (6) applications of the rules or patterns concerned to the area of the improvement and design of new types of flow movement laser devices.

As far as non-equilibrium flow is concerned, besides the generality of fluid dynamics conservation equations and state equations, it is still necessary to supplement the additional equation sets to reflect the increased entropy of non-reversible processes and to study the corresponding physical processes. In the last ten years or so, research on the matching or coordination of flow movement laser device capabilities, fluid dynamics and the physics of lasers have merged with each other, and research on this type of population inversion non-equilibrium flow as well as on its mutual interactions with strong radiation fields have been appropriate to achieve rapid development. This is precisely what is needed to analyse flow movement laser device characteristics and to carry out, on new boundary assumptions, projections and designs for new laser devices (this is particularly true for large scale devices). Also, for the study of this type of non-equilibrium characteristics and laser physics itself, this has important scientific value.

The factors and parameters involved in this type of problem are relatively numerous. The equations are complicated, and they are sensitive to changes. Each type is analyzed through simplified conditions, and, although, for certain problems, this gives rise to the effects of definite and obvious trends, in order to reflect the several rules or patterns and special characteristics in the actual problems, as well as to give the parameters needed in actual applications enough precision of numerical data, it is necessary to

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select for use relatively complicated rationalized and simplified
models. In this way, due to the fact that equations which are too
complicated are not capable of analysis, it is only necessary to carry
out numerical value simulation calculations. This article does not
actually introduce the concerned non-equilibrium macroanalysis work,
but, instead, reintroduces the work of the Acadamia Sinica's Mechanics
Research Institute over the last ten years, on synthesizing the
research on the characteristics of flow movement lasers and the work
of simulation calculations on the mutual effects of strong radiation
and population inversion non-equilibrium flows of this type.

II. QUASI-ONE-DIMENSIONAL POPULATION INVERSION NON-EQUILIBRIUM FLOW CALCULATIONS

It was theoretical calculations that predicted that the cooling
of high speed flow movements would be able to make non-equilibrium
flows produce population inversions. Because of this, people were led
to the test manufacture of the gas movement laser [3,4].
Quasi-one-dimensional non-equilibrium flow calculations
give rise to important effects on gas flow laser devices and on the
production and development of other flow movement laser devices as
well.

Quasi-one-dimensional non-equilibrium calculation methods consist
of the setting up of sets of simultaneous quasi-one-dimensional flow
movement equations and relaxation equations and the solving of them.
Roughly speaking, these can be divided into the two categories of
steady state methods [4] and non-steady state methods [5]. Steady
state methods involve the solving of normal differential equation sets
after the occurrence of steady state conditions by the use of the
Rungge-Kutta methods or integration methods. These types of methods,
at the points of singularity which appear in the vicinity of sonic
points in the throat paths of compression-diffusion jet tubes, are not
capable of making a unified solution for subsonic, transonic, and
supersonic speed zones. It is generally assumed that, in jet tubes,
the subsonic speed portions are equilibrium flows, and, by adjusting
the parameters to give the throat passage initial conditions, then,

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beginning from the vicinity of the throat passage, one calculates in order to obtain a convergence solution. Non-steady state methods involve first assuming that, in non-steady state equation sets, the various unknown variables, at time $t=0$, form an initial distribution. Then, on the basis of a certain time increment and difference standard, one solves for the various values in the distributions at times $t+\varDelta t$. This continues until the various parameters are all at convergence and one solves for their constant values. The equation sets, in the entire jet tube, are all of the double curve type. The throat passage area does not show the existence of points of singularity. And, it is possible, in the subsonic, transonic, and supersonic speed zones, to make a unified solution. In the 1970s, we respectively selected for use these two types of methods, and, on $CO_2\text{-}N_2\text{-}H_2O$ component non-equilibrium flows, conducted the work described below.

1. Relaxation Models, Data, and Equations. On the basis of work which had already been done in a relatively systematic analysis and treatment, we presented a relatively reasonable 3 vibrational mode, 4 temperature relaxation model [7] and gave unified, broadly applicable relaxation speed data [6] and a relatively rigorous equation set [7,8].

2. On Small Signal Gain Calculations. We employed for use the improved model described above, equations and processing data. We ignored radiation quantities and calculated the influence of small signal gain and various other factors [7]. We made a comparison with the experimental data and the results of calculations by other authors, and this showed that our calculations matched even better with the experiments. Moreover, from the angle of the presentation of the small signal gain, we arrived at several rules for improving the characteristics of laser devices.

3. A Comparison of the Results of Calculations Using Steady State and Non-Steady State Methods. We respectively employed these two types of methods on combustion type $CO_2\text{-}N_2\text{-}H_2O$ gas flow laser systems and made calculations and analyses [9]. The results showed that the rules or patterns which were obtained from these two methods were basically the same. However, on the small signal gain - blockage temperature graph, there were differences between the two in that, if one takes the non-steady state results in the high temperature

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direction and translates them approximately 100K more or less, that is, makes them closely duplicate the results for steaty states, it shows that the two are reasonablly similar. Moreover, the translation toward the high temperature makes it possible to explain the fact that it is, compared to the non-steady state calculations that have already been made and to the freezing effects in the subsonic speed zone, equivalent to a drop of approximately 100K more or less in the throat passage. Moreover, this type of drop has a tendency to increase along with a rise in the blockage or congealing temperature. This is only possible to arrive at when one makes a comparison with non-steady state results, reflecting the superiority of the non-steady state method. However, the steady state method produces savings in time, and has the advantages of being easy to work into experiments, and, in conjunction with the non-steady state method, is suitable to use in getting crude, rapidly arrived at macro-pattern type results.

III. A SIMPLIFIED MODEL FOR MIXED NON-EQUILIBRIUM FLOW CALCULATIONS

After-mix type gas flow laser devices and chemical laser devices all require the determination of mixed non-equilibrium flow calculations. In two supersonic speed flow mixing processes, due to the complexity of the laminar flow or turbulence flow mixing, the boundry layers, viscosity, and attack wave and other similar factors, the created gas flow losses cause very complicated problems. At the present time, even though we already have a relatively rigorous two-dimensional calculation method [10], the amount of work is very large, and it is not appropriate for use in large amounts of calculations. Because of this, we developed a number of one-dimensional simplified models.

1. The Improved "Leaking Tube" Model. Among the simplified models, the "leaking tube" model is used the most widely [11]. We select for use this model's basic method, and, on mixing area form curves make use respectively of the two types of curve forms - the straight line and the second order curve. Moreover, tying in jet tube blockage condtions, we fix initial conditions, calculate the mixing CO_2 gas flow laser device characteristics [12], and arrive at the mixing area curve form length and jet tube blockage conditions and the patterns or rules for their effects on small signal gain.

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2. The "Gradual Mixing" and "Instantaneous Mixing" Models. Let us select similar one-dimensional mixing charts, and assume that the parameters are all uniformly for two parallel flow bodies with no gap between them (G flow and J flow) and that they mutually intermix to become a mixed flow (M flow). The M flow parameters have their average values determined, on the corresponding cross section inside the mixing area, by the parameters corresponding to the two flows G and J on the cross section perpendicular to the direction of flow. Moreover, along the direction of the flow, according to the given mixing area's form curve, a point by point utilization of integration forms a one-dimensional steady state flow equation set and relaxation equation set to be solved simultaneously, in order to precisely determine the various instantaneous mixing areas. This is called the "gradual mixing" model [13]. As far as the G and J flow calculations and their respective results for $N_2 + H_2O$ and $CO_2 + H_2O$ are concerned, they square satisfactorily with the solutions obtained on the basis of the two-dimensional Navier-Stokes equations [9]. On the basis of this model, we considered the effects of the initial conditions and the mixing area form curves on small signal gain. Also, due to the fact that what we were interested in was only the gain for the outside of the mixing areas, the calculations discussed above demonstrate that the mixing length has no clear effect on this. Therefore, we also presented the even more simplified "instantaneous mixing" model [14], that is, assuming that the two flows in the jet tube exit are immediately and uniformly mixed. To the rear of that, they, then, act as a single non-equilibrium flow for the same cross section. On the basis of a one-dimensional steady state flow conservation equation and relaxation equation set, one solves, and, in this way, it is possible to calculate the results even faster. This is useful for large amounts of calculations. According to this model, we calculated and analysed the flow speed, temperature, constituents, and other similar factors and their effects on gain.

3. Two-Dimensional Simplified Method for Two Parallel Flows
Carrying Chemical Reactions. Giving consideration to the fact that,
in laser instruments, the types of activated particles are relatively
numerous, it is difficult to select for use the normal "flame slice
approximation" model [15] that is used in the series expansion method
solution. Moreover, the "flame slice approximation" as well as the
quasi-one-dimensional mixing model discussed above both also require,
from other tracks, to precisely determine the mixing length at which
it is introduced. Because of this, we, on the basis of
two-dimensional laminar flow compression boundary layer equations,
selected for use a type of passive limited difference standard, and.
on the two parallel flow diffusion mixture chemical reaction problem,
carried out calculations [16]. It is possible to do this much more
simply and conveniently than it is possible to directly solve the
two-dimensional Navier-Stokes equation, and there is no need for an
assumption of mixing length. One solves for the two boundary surface
curves between the mixing areas (including those with and without
chemical reaction) and the non-mixing areas. Using this method, we
studied, in continuous wave HF chemical lasers, the gas flow speed,
temperature, as well as chemical reactions, their speed coefficients,
and other similar factors with their effects on activated state HF
concentration and small signal gain [17].

IV. THE TREATMENT OF THE MUTUAL EFFECTS OF RADIATION FIELDS ON
NON-EQUILIBRIUM FLOWS

In order to study the functions of lasers producing strong
radiation and to study the non-equilibrium flow problems involved with
the important effects caused by radiation, electrical discharges,
chemical reactions and various types of relaxation, it is necessary to
really do a treatment of the radiation fields in them. During the
early period, when calculations were made of the distributions of
radiation fields in cavities, what was considered was a situation in
which, in a vacuum, there was no activation medium [18].

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[19] calculated the three dimensional distribution of radiation fields in activated cavities. We did the work shown below.

1. Making appropriate adjustments to the difference methods that already existed to make them capable of being appropriate to use in even broader ranges. We discovered that the calculation methods in [19] were appropriate within the infinitely small ranges of the various difference nodal points but also led to the introduction of the inappropriate assumption of taking the various adjacent propagation surfaces to be all functioning as uniform spherical surfaces. If adjustments were not made to this, particularly in the case of cavity bodies with relatively small degrees of coupling, then it would not be possible to reach stable solutions. Because of this, we selected for use, in empty cavities, methods similar to the single parameter empirical formula set up between the degrees of coupling of the "diffraction distributions" and the "uniform spherical surface wave distributions" and made adjustments from this. As a result of this, it was possible, for all the different degrees of coupling, to easily obtain stable solutions [21].

2. Calculations of the radiation energy densities in resonant cavities. In resonance cavities, the radiation energy density is normally solved from the light reflection bundle on the basis of the "light strength superposition". For lasers, this type of strong phase interference luminosity can, in principle, only be calculated on the basis of "field strength superposition". We took the same instrument and separately made use of two types of superposition formulas to make comparative calculations. The results demonstrated that, without any question, the overall light strength and saturation gain coefficient both show clear differences. This reflects, in the cavities, the radiation energy densities and the saturation gains and all of them must be calculated on the basis of field strength superposition. However, the output radiation field phase and amplitude distribution probabilities were all the same. Corresponding output powers were also very close. This demonstrates that, on the basis of light strength superposition, it is possible to basically arrive at accurate calculations for the output radiation fields and powers [22].

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3. The strict derivation of commonly used equations for the calculation of radiation fields and an investigation of integration methods for doing calculations on activation cavities. In activation media with dielectric coefficients of unusual magnitudes, the wave motion equations which act as the basis for the normal calculations of field distributions certainly have yet to be verified. Furthermore, it is certainly not possible to derive the normal Fresnel-Kirchoff diffraction equations and this makes integration methods lose their foundation. The calculations we have now all make use of difference methods. However, difference methods only make it possible, on the basis of the light bundle propagation paths, to carry a point to point analysis. As far as complicated cavity form structures go, for example, the important Z form folded orthogonal branch common focus instable cavities, it is only possible to select for use the corresponding hollow center drawn out cavity simulation. The two of these are clearly very different. Because of this, we strictly begin from Maxwell equations, considering gas media complex diffraction rates with real parts that are constants and approximately equal to 1. Moreover, the fact that their imaginary parts have no uniformity is only due to the non-uniformity of the gain parameters. Also, we did concrete calculations for the orders of magnitude of the quantities concerned, and we arrived at the fact that [23] : (1) we could demonstrate that, in non-uniform activated gases, the electric field strength still comes from similar wave motion equations. However, their complex diffraction rates are not constants. (2) On the basis of these equations, we selected for use the normal classical field theory methods, combining calculations of the orders of magnitude of the parameters concerned in actual devices, giving an integral formula for expressing, to an accuracy of 1%, the electrical field strengths in gas media. This is equivalent to considering activated media gains according to new principles. Due to the fact that it is possible to derive various types of methods for calculating field distributions, this causes them to be set up on a relatively firm basis of theoretical principle. Moreover, it is possible to estimate the degree of accuracy of the calculations. giving the approximation conditions. Moreover, in principle, it is possible to use this as a basis to make integration calculations. (3) On the basis of the

magnitude of the changes in parameters, one takes the surface
integration resolution units to be several large areas. Within each
large area, one takes the parameters to be constants. Again, on the
basis of the magnitude of phase changes, these are divided into small
areas. Also, on the basis of the Cornu spiral integration method,
in normal mechanisms, it is easily possible to carry out an
integraton, basically solving the problem of using integration methods
to do calculations for activated cavities.

4. The Appropriateness, When Calculating Output Powers, of
Simplification Assumptions When Selecting for Use Uniform
Distributions of the Various Cross Sections of Radiation Fields
Perpendicular to the Light Axis. At times when one has to do
non-specific studies of the light sheaf mass and output form without
considering output power, in order to avoid the complex calculations
involved with radiation field propagation equations, one can very
greatly simplify the problem by assuming a uniform distribution of
radiation fields in the various cross sections along the light axis.
However, what is the reliability of the results that are obtained by
the use of this type of assumption? We, on the basis of an assumption
of uniform distributions, came forward with a type of crude formula
for estimating calculations [24] which can be expressed by simple
algebraic forms and used on a folded cavity of (n-1) courses. We used
this to calculate several sets of empirical data which had been
reported in references (this data was relatively complete, specific,
and was the result of calculations done on the basis of radiation
field distributions). At the same time, we, again, on the basis of
strict radiation field distributions, calculated these numerical data
[21,22]. The results demonstrated that, it goes without saying the
single course cavity or "Z" type folded cavity, with high degrees of
coupling or low degrees of coupling, and, on the basis of the output
powers calculated from the crude estimation formula, tracked in all
cases with the empirical data and the corresponding results calculated
on the basis of field distributions matched up very well. Because of
this, they were sufficient to demonstrate, in a concrete fashion,
that, when calculating output powers, the assumption of uniformity for
radiation fields in the various cross sections perpendicular to the
light axis certainly does have a sufficiently reliable
appropriateness for use.

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V. SIMULATION CALCULATION PLANS FOR TRANSVERSE FLOW, ELECTRICAL EXCITATION CO_2 LASERS

When one considers the calculation plans that are already in the refernces [26-28], none is capable of doing a good job in the simulation of the various forms of structures that are often found in electrical discharge areas. They also lack applicability for use in the conditions of stable oscillation selected in specific analyses. Moreover, the models which are used are only limited to one-dimension. We did the work detailed below.

1. The Presentation of a Simple and Appropriate Model for Electrical Discharge Areas. When we simulated actual devices, forming a simple calculation model for one-dimensional flows and quasi-two-dimensional electrical discharges, we were able, for the light cavity areas of devices and within the various types of electrical discharge areas, to make a quasi-two-dimensional simulation calculation for their special characteristics. After making a reasonable selection for E/N, it was possible to make the calculated small signal gain peak values come into line with empirical results. Moreover, as far as the obtaining of two-dimensional distributions for small signal gains within electrical discharge areas in different structures is concerned, their basic forms were also able to approximate closely empirical measurements.

2. The Presentation of a Simplified Calculation Method for Simulated Transverse Flow Electrical Discharge Laser Output Powers. As far as the selection for use of the simplified discharge area model which was discussed above is concerned, in the equations, one sees the addition of quantities for uniformly distributed radiation on the various cross sections perpendicular to the axis of the light. Moreover, respective situations call for the selection of appropriate stable oscillation conditions to arrive at a set of simplified methods or plans for the calculation of cavity saturations and gains and output powers [30]. On the basis of these methods, we calculated and analysed media for different flow speed conditions, electrical discharge area lengths, electron densities, cavity lens lengths, cavity lens center positons, degrees of output coupling, and the effects of such factors on output powers as well as the patterns of their changes. Moreover, from this emerged several workable suggestions for raising the device output power angle and improving the devices and their designs [31].

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3. The Presentation of a Set of Simplified Calculation Methods for Simulated Transverse Flow Electrical Discharge Laser Efficiencies. As far as our concrete definition and precise calculation of the overall power of flow movement electrtical discharge lasers $\bar{\eta}_{EI}$ is concerned, the input electrical energy transfer becomes the efficiency $\bar{\eta}_{Er}$ of the laser upper energy state oscillation energy. The laser upper energy state oscillation energy transfer becomes the output light energy efficiency $\bar{\eta}_{vI}$. Moreover, under conditions of differing flow speeds and differing currents, we calculated the electrical discharge area length, the electron density, the relative positions of the electrodes and the light cavity, the degree of coupling and the different effects of such factors as these on $\bar{\eta}_{EI}, \bar{\eta}_{Er}, \bar{\eta}_{vI}$ as well as the rules for their changes. Moreover, from the angle of raising the overall device output power and various types of efficiencies, this brought to light several corresponding possible suggestions concerning device design [32].

VI. SOME RULES FOR THE MUTUAL EFFECTS OF RADIATION, ELECTRICAL DISCHARGES, AND NON-EQUILIBRIUM (FLOWING ACTIVATED MEDIA)   22

In cavities, the mutual effects on saturation and gain for radiation fields, electrical discharges, and flowing activated media change with variations in various factors such as cavity body structure, radiation field distribution form, media characteristics and their flow movement forms. The rules of change for these factors can also reflect the basic physical mechanisms inside lasers. The current literature, as far as the saturation and gain in laser devices and these types of important characteristic are concerned - aside from a few approximate analytical solution expressions under simplified conditions - have still not seen a concrete description and analysis of the rules for changes concerning them. We, as far as actual cavity bodies of $N_2\text{-}CO_2$ system lasers are concerned, and according to rigorous equations, made numerical value simulation calculations, and the results we achieved plus the analysis of them, in general, furnish as the several rules set out below.

1. Basic Rules for the Changes in the Flowing Activated Media Saturation and Gain Parameter Distribution G(x) as It Varies With the Light Distribution I(x) [33]. (1) In areas where I(x) increases abruptly with x, G(x) abruptly goes down. (2) In areas where I(x) basically does not change, G(x), in line with x, shows a monotonic drop along a negative exponential curve. Moreover, the larger the I(x) value is, the steeper the drop. (3) In areas where I(x) drops precipitately along with x, G(x) has a corresponding return upward.

2. For Given Different Light Strengths I, Rules for Changes in Flowing Activated Media Saturations and Gains According to Electrical Excitation Conditions. (1) In areas where gas flows enter electrical discharges, small signal gains begin at zero and, along with x, rapidly increase. (2) In light cavity and electrical discharge overlap areas, the G-x curve varies with differences in the light strength I. a. When I is relatively small, G continues going up. However, following along with an increase in I, G gets smaller in line with the x increase gradient. b. When I increases to a certain level, G, along with changes in x, continues to show the appearance of a low valley and high peak. c. When I is relatively strong, G goes down quickly and tends toward a certain fixed value. d. When I is extremely strong, G goes down extremely fast and does not show a stable value. (3) After the areas where activated gas flows give off electrical discharges, G(x), following the rules for changes in I(x) is the same as when [33] has no electrical discharge area.

All the rules above also--from the size of media population inversions--follow along with microscopic dynamic mechanisms in systems (that is, with and without pumping in, with and without radiation fields, as well as the magnitudes of their strengths, various types of relaxation transfer energy and radiation transfer energies, as well as their speed magnitudes, and so on) and change their states with differences in these factors. This gives rise to the upper and lower laser energy level energy transfer amounts supplied to be slow, fast, adequate and deficient as changes occur in the situation. The appropriate explanations for this [33,30] also, on the basis of this, put forward a number of opinions [25] on the design of high energy flow movement laser device light cavities.

3. At Times When Other Conditions Are the Same, Rules for Changes in the Small Signal Gain G_0 and the Saturation Gain G Following Along With the Media Flow Speed u. From the G_i-x curve, one can see that, when u is relatively small, within electrical excitation areas, G_i follows x in a relatively steep rise and arrives at a stable value, continuing straight through until it flows out of the electrical excitation area (one character unreadable) and follows x in a steep decline. When u increases, G_0 , in electrical excitation areas, follows the rise of x and, after flowing out of the electrical excitation area, follows x in a decline, both of which are gradual. As far as a given electrical excitation area length is concerned, following an increase in u, the peak value of G_0 drops down and moves along the direction of the flow movement. In electrical excitation areas, the stable area for G_t will contract until it disappears. Moreover, when u increases to a certain appropriate value, it is possible to make the medium, after flowing out of the electrical excitation area, maintain a phase of stability. From the G-x curve, it is possible to see that, when u increases, the curve has the same type of tendency to change toward the direction of reduction in I. Moreover, as concerns light cavity structures with relatively numerous lens slices or plates located in the electrical excitation area, these types of changes are even more obvious. These all reflect the important effect of media flow speeds. Moreover, they are all capable of using non-equilibrium media flow speeds and the rates of speed at which in-pumping is received, the competition between various types of transmission or transfer energy speeds, and the increasing and decreasing effects of microscopic dynamic mechanisms to supply explanations.

In the last ten years, we, in the process of test producing high power laser devices, have ammalgamated fluid dynamics and laser physics, and, in the area of simulation calculations of non-equilibrium flows and their mutual effects on strong radiation for population inversions, have done a considerable amount of work. We already have a set basically appropriate for use in studying simulation calculation methods and procedures for various types of flow movement laser devices. We did comparative systems analysis

research on several basic characteristics and patterns in non-equilibrium flows for this type of population inversion. Now we are considering the combination of the actual effects from raising gas pressure, continuous frequency adjustment, repetitive pulses, as well as making use of other media systems and other similar areas to expand a step further the range of the study.

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